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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The work has progressed well and we have:
(i) Developed an automatic data acquisition method.
(ii) Determined the compliance of the specimen, both experimentally and theoretically
(iii) Measured the static adhesive facture energy, G_c.
(iv) Measured the cyclic fatigue behaviour at 25°C and 55% r.h.

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1. INTRODUCTION

The bonded joints employed were tapered-double cantilever beam (TDCB) specimens, which consist of aluminium alloy substrates (BS 5083 grade), pretreated using various surface treatments, and bonded with '3M AF 163' film adhesive. The details of the preparation of the TDCB joints were reported previously [1].

2. OVERALL PROGRESS

The work has progressed well and in the last six months we have:

(i) Developed an automatic method for monitoring the rate of crack growth.

(ii) Determined the compliance of the TDCB specimens as a function of crack length. The crack length values were measured firstly by using the above method and, secondly, by using a travelling microscope. These experimental values have been compared to the theoretical value, where the rate of change of compliance, dC/da, with crack length is given by:

$$\frac{dC}{da} = \frac{8m}{Eb} \qquad (1)$$

where E is the modulus of the substrate, b is the width of the specimen, C is the compliance (C= *displacement* (δ)/*load* (P)) and m is the specimen contour given by:

$$m = \frac{3a^2}{d^3} + \frac{1}{d} \qquad (2)$$

where d is the height of the contoured beam at a crack length a.

(iii) Determined the static value of the adhesive fracture energy, G_c, (also termed the 'critical strain energy release rate') for a test rate of 1 mm/min. The value of G_c is given by:

$$G_c = \frac{P_c}{2b} \cdot \frac{dC}{da} \qquad (3)$$

where P_c is the load for the onset of crack growth. Obviously, the term dC/da is obtained from the above work, and hence the importance of ascertaining accurate values of dC/da.

(iv) Determined the fatigue behaviour at a frequency of 5 Hz and a displacement ratio (= $\delta_{min}/\delta_{max}$) of 0.5. The data has been plotted in the form of the rate of crack growth, da/dN, per cycle versus the maximum applied strain energy release rate, G_{max}, in each cycle. Where the value of G_{max} is given by:

$$G_{max} = \frac{P_{max}}{2b} \cdot \frac{dC}{da} \qquad (4)$$

where P_{max} is the maximum load applied to the specimen per cycle.

3. RESULTS

3.1 Automatic data acquisition system

This system consists of using an electrical potential method for measuring the length of the crack. The electrical potential method is an indirect d.c. potential technique and involves the use of a gauge bonded onto the side of the specimen, over the adhesive layer and adjacent substrates. The gauge (called a 'Krak Gage') is a plastic foil with a deposited metal film on its surface. The plastic foil provides both support and insulation from the metallic substrates. A small current of the order of 100 mA is passed through the foil, and when the crack propagates and breaks the foil there is a large change in the resistance of the gauge, hence yielding a change in the d.c. potential. The change in potential is relayed from the leads soldered onto the gauge to an amplifier (called a 'Fractomat') which gives a voltage reading. The signal is then relayed to a 'Mac Lab' data acquisition unit. The 'Mac Lab' is connected to a 'Macintosh PC'. The PC acquires the change in crack length as a function of the time (i.e. number of cycles) and a computer program, based on the ASTM Method E647-88, calculates the rate of crack growth per cycle, da/dN. The PC also acquires the signals of the maximum load and displacement being applied to the specimen, and therefore the corresponding value of G_{max} is deduced.

To validate the system the compliance of the TDCB joint was deduced by plotting the compliance versus the crack length; where the crack length was determined by the automatic monitoring system and visually, using a travelling microscope. The agreement in the experimental results was excellent. The agreement with the theoretically calculated value, using equations (1) and (2) was also excellent. The results are shown below.

Table 1. Compliance calibration results

Method	dC/da (x 10^{-5}) (N^{-1})
Experimental- visual	2.10
Experimental- automatic	2.05
Theoretical	2.05

3.2 Static fracture behaviour

The aluminium alloy beams were subjected to a chromic-acid etch pretreatment and then bonded using the 'AF 163' adhesive. The static value of the adhesive fracture energy, G_c, (also termed the 'critical strain energy release rate') for a test rate of 1 mm/min was determined using Equation (4) and was found to be 1720 J/m^2. The locus of failure was cohesive through the adhesive layer.

3.3. Fatigue fracture behaviour

The aluminium alloy beams were subjected to a chromic-acid etch (CAE) pretreatment and then bonded using the 'AF 163' adhesive. The fatigue crack growth behaviour was determined at a frequency of 5 Hz and a displacement ratio of 0.5. The test temperature was 25°C and the relative humidity was 55% r.h. The results are shown in Figure 1. In all cases the locus of failure was cohesive through the adhesive layer. A threshold value of the adhesive fracture energy, G_{th}, from the cyclic fatigue tests is indicated in Figure 1. The value of the threshold value of the adhesive fracture energy, G_{th}, represents the value below which fatigue failure in the given environment would not be observed. From Figure 1, the value of G_{th} is about 550 J/m^2. This represents approximately 30% of the initial static value which was obtained; i.e. 1720 J/m^2.

4. FUTURE WORK

The future work planned is:

(i) To study whether the automatic data acquisition system functions satisfactorily when the fatigue tests are conducted in water.

(ii) To measure the fatigue crack growth behaviour of the aluminium alloy/'AF 163' joints when the tests are conducted in water; and to determine the threshold value of the adhesive fracture energy, G_{th}, in an aqueous environment.

(iii) To examine the effect of different surface pretreatments, including primers, for the aluminium alloy on the fatigue crack growth behaviour of the joints.

(iv) To also examine the fatigue crack growth behaviour of carbon-fibre thermoplastic composites bonded using the 'AF163' adhesive. The composite will be a carbon-fibre/poly(ether-ether ketone) material, and will be corona treated prior to bonding.

5. ACKNOWLEDGEMENTS

The authors would like to thank the Ford Motor Co. for assistance in purchasing the 'Fractomat' equipment.

6. REFERENCES

[1] A.J. Kinloch and M. Fernando, '2nd Interim Report', US Army, ERO, June 1993.

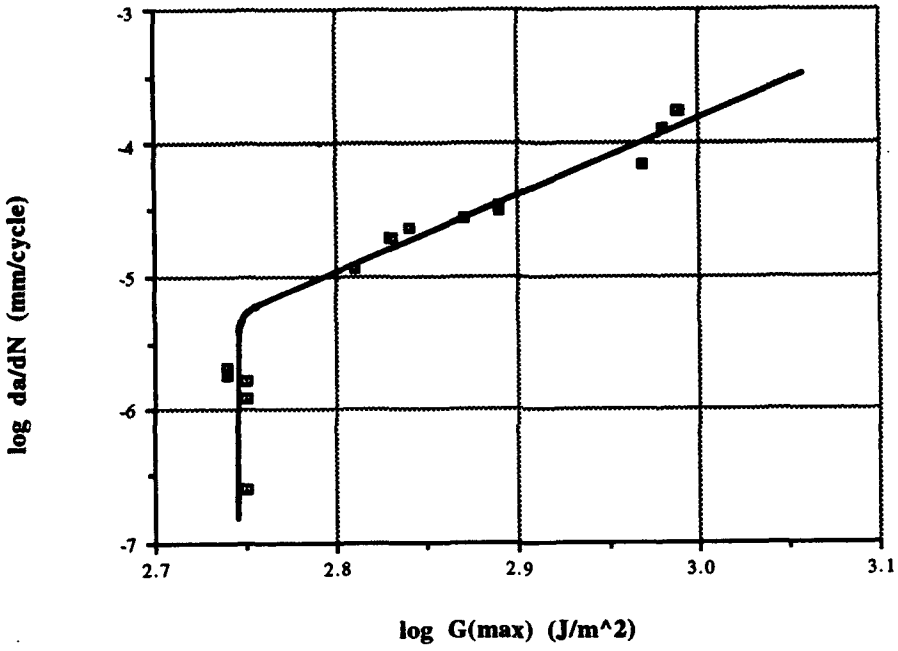

Figure 1 Fatigue behaviour of AF163 joints